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ABSTRACT

This interdisciplinary packet of materials on mapping is intended for grades 7-12. The lessons are organized around themes: location, navigation, information, and exploration. Each lesson has an introductory text and two main activities. Students learn basic mapmaking and map-reading skills and see how maps help answer fundamental geographic questions. The packet contains two posters that illustrate the development of mapping complete with a time line. Included in the packet are four activity sheets with several suggested activities, a teaching guide, and evaluation sheet. A vocabulary list accompanies each activity sheet. The activity sheets are entitled: (1) "What else is here?"; (2) "How do we know where we are?"; (3) "How do we know where we're going?"; and (4) "Where do we go from here?" Contains 42 references. (EH)

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EXPLORING MAPS TEACHING PACKET

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UNITED STATES DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

1992

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U.S. Department of the Interior
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Exploring Maps

Teaching Guide

Introduction

Exploring Maps is an interdisciplinary set of materials on mapping for grades 7-12. Students will learn basic mapmaking and map-reading skills and will see how maps can answer fundamental geographic questions: "Where am I?" "What else is here?" "Where am I going?"

The map images and activities in this packet can be used in various courses, including geography, history, math, art, English, and the sciences. The images on the enclosed poster and the educational activities have been selected both to enrich our knowledge of mapping itself and to present maps as representations of reality.

Contents of this packet

- Two posters illustrating the development of mapping on the front; map-related texts and a do-it-yourself time line on the reverse.
- Teaching guide.
- Four activity sheets, each with several suggested activities.
- Evaluation sheet.

How to use this packet

The fronts of the two posters can be displayed side by side, producing a timeline showing the development of maps since 900 B.C. The front of one poster can be displayed above the reverse of the other poster, producing a more detailed view of the same period. The reverse sides of the posters can be displayed together, producing a do-it-yourself timeline and literary excerpts with which a class can work. The writings on the reverse, also in the form of a timeline, can be photocopied and distributed to the class to stimulate writing assignments and discussions or to use with the activities.

References listed in the bibliography are recommended further reading; many of these books helped shape the content of the posters and activities.

The lessons are organized around themes: location, navigation, information, and exploration. A lesson has an introductory text and two main activities; the format is designed for easy photocopying so that every student will have a copy. Most activities can be completed within 2 hours, but some could become major projects. With each activity is a list of needed materials, the estimated time for completion, step-by-step instructions, and recommended readings and additional activities. Lists of important terms are included in most activities, but definitions are to be collected by students to make a glossary. Important notes about each lesson, definitions of glossary words, and answers to questions are included below.

The lessons

Location

Activities

Tools of the Ancients (making instruments and measuring latitude and longitude)

A Place in Time (documenting changing characteristics using maps)

Notes

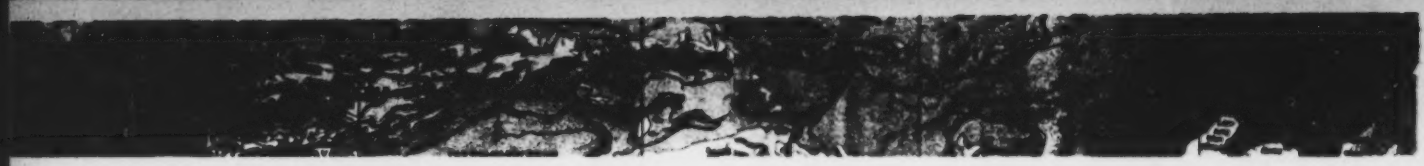
This lesson explores the methods of characterizing places, from the five senses to sophisticated tools of measurement. Every place has important characteristics and a unique location relative to other places. Latitude and longitude measurements indicate a place's absolute location on the globe.

Tools of the Ancients has students make a sundial and an instrument similar to a sextant. The students translate observations from these instruments into latitude and longitude.

A Place in Time has students document the history of a place. Students do research, organize information, and make maps and a timeline for a place of their choice.

Glossary

dead reckoning: The estimation of a ship's position from the distance according to the ship's log and the course steered by the compass, with corrections for currents and other factors, but without astronomical observations.



Greenwich time: Mean solar time of the meridian of Greenwich, England, used by most navigators and adopted as the basis of standard time throughout the world.

landmark: Any prominent object on land that can be used in determing a location or direction.

latitude: Angular distance measured in degrees, minutes, and seconds north and south to the geographic poles from the equator.

longitude: Angular distance measured in degrees, minutes, and seconds 180 degrees east and west from the Prime Meridian, the imaginary north-south line through Greenwich, England.

magnetic compass: An instrument having a magnetic needle to indicate magnetic north.

mappa mundi: From two Latin words meaning tablecloth and world, a graphic or verbal representation of the world as understood in the Middle Ages in Europe.

marine chronometer: A portable timekeeper with a special mechanism for ensuring and adjusting its accuracy, for use in determining longitude at sea.

photogrammetry: The techniques used to obtain reliable measurements from photographs.

planetable: A device for plotting survey data directly from field observation. Consists of a drawing board on a tripod with a sighting instrument to measure and plot angles.

planisphere: A projection or representation of the whole or a part of a sphere on a plane.

portolan chart: A type of sea chart common in the Middle Ages that was used for navigation at sea. Characterized by rhumb lines, or lines of constant compass heading, and the names of ports. From the Italian, portolano, a collection of sailing directions.

remote sensing: The process of detecting or monitoring the properties of an object without physically contacting the object.

sextant: An astronomical instrument for measuring angles, primarily altitudes of celestial bodies, to determine latitude.

surveying: The techniques used to make measurements in space to determine the relative positions of map features.

theodolite: A precise surveying instrument having a telescopic sight for measuring horizontal and vertical angles.

triangulation: A method of surveying in which the stations are points on the ground at the vertices of a chain or network of triangles. The angles of the triangles are measured instrumentally and the sides are derived by computation from selected sides or bases, the lengths of which are obtained by direcrt measurement on the ground or by computation from other triangles.

Answers to questions—

Tools of the Ancients; Columbus...

Extension 1. Students will observe slightly different values; this is normal. The range of values will vary. The "best" value is probably an average (the sum of observations divided by the number of observations).

Extension 3. Columbus might not have decided to sail west, since the trip to the Orient would have been so long. Spain's monarchs, Ferdinand and Isabella might not have sponsored a trip that risky.

Extension 4. The analemma shows two kinds of information (1) how high the Sun is in the sky on each day of the year at noon local time on the meridian on which the analemma is centered; and (2) the difference between solar noon time and standard noon according to the clock. The analemma can be placed on any meridian. Apparent changes in the height of the Sun in the sky result from the tilt of the Earth's axis of rotation. The tilt is constant, but at different positions in the Earth's orbit around the Sun, the changing effect causes the seasons. Variation in day length is the combined effect of three factors. The speed of the Earth in its elliptical orbit varies. This effect combined with the effects of the tilt of the Earth's axis of rotation and the counterclockwise direction of rotation and revolution produces the variations in local noon shown on the horizontal axis of the analemma.

Tools of the Ancients; Local Time...

Instruction 6. The sun is at its highest when the shadow is shortest. The clock time of this observation differs to the east and west. As the Earth rotates toward the east, local noon time is earlier in the east.

Extension 1. The angular difference between geographic north and magnetic north is the difference between the direction indicated by the sundial at local noon and the direction to north as indicated by a compass needle. Geographic north is the north end of the Earth's axis of rotation. Magnetic north is the north end of the Earth's magnetic field.

Extension 2. To determine the number of degrees in a time zone, divide 360 degrees by 24 hours (360/24=15). To calculate your longitude knowing the time difference from Greenwich, multiply the number of hours difference by 15 degrees. For example, if the time in Greenwich is 6 hours ahead of the time where you are, your approximate longitude is 6 x 15, or about 90 degrees west of Greenwich.

Navigation

Activities

Make a Mercator Projection
(transforming the globe to a flat sheet)

In the Wake of Lewis and Clark
(following a trail)

Notes

This lesson explores how maps have been used in navigation. Travelers collected observations to keep track of their positions and plotted this information on maps. Navigators and mapmakers devised maps for different needs, translating the three-dimensional globe onto flat maps, sometimes inventing projections with special characteristics.

Make a Mercator Projection has students make a close approximation of the most common projection in use today.

In the Wake of Lewis and Clark has students trace the route of this expedition and plan a trip that follows a part of this route.

Glossary—none

Answers to questions

Make a Mercator Projection

Procedure 14. The outlining of continents need be only as detailed as required to use the map for plotting a few routes. Columbus' route should go from southwestern Spain to San Salvador in the Caribbean; that is, from latitude 37° N, longitude 7° W, to latitude 24° N, longitude 74° 30'. From your hometown, plot a route to any point on the western coast of Africa. From Kuwait, plot an ocean route to Tokyo. You cannot plot polar explorations because polar areas are not shown on this projection.

Extension 1. To compare properties of projections, collect several maps and look on each for the name of the projection, usually in the lower right or left corner. Different publishers may prefer different projections.

In the Wake of Lewis and Clark

Procedure 3. To estimate how far students might be able to travel in a week, they must decide on a type of boat, estimate its speed and the number of hours a day they will travel. Obstacles include dams, other structures, and river traffic. Supplies can be purchased en route or cached ahead of time. Have students compare their lists of supplies with the list from Lewis and Clark's journal.

Responsibilities in the group might include leading, navigating, handling food, handling finances, keeping written records, taking photographs, conducting scientific investigations, etc. Costs might be paid by travelers themselves and their families or by a sponsoring organization that might want to dictate part of the purpose of the trip. Students might accomplish a variety of goals: documenting conditions along the route, following the route and schedule of the original explorers as closely as possible, checking the explorers' celestial observations using today's tools, etc.

Information

Activities

On the Trail of Knowledge (plotting data on maps to see spatial relationships)

Maps With a Spin (making thematic maps that convey a message)

Notes

This lesson explores thematic maps: maps that show information on single topics. Characteristics of thematic maps are scale, context, and theme. The design of a thematic map considers the purpose of the map. A typical thematic map consists of a base map with selected spatial data plotted on it. A thematic map needs a descriptive title and an explanation. In plotting spatial data and making thematic maps, students will come to appreciate the diversity of information that can be shown on thematic maps.

On the Trail of Knowledge has students plot spatial data on a base map to see the information better. The students evaluate the data, plot points, and consider what the map shows.

Maps With a Spin has students use maps to present alternative proposals for the location of a new airport. Students gather data, make maps, and represent different points of view in a mock town meeting.

Glossary

base map: a map showing certain fundamental information on which can be compiled additional, specialized data.

compilation: production of a new map from existing maps, aerial photographs, and other sources.

context: the interrelated conditions in which something exists.

distortion: the lack of proper proportion; directions, shapes, distances, and sizes of areas may be shown inaccurately.

generalization: the simplification of data by eliminating unneeded detailed data.

grouping: the simplification of data by sorting data into similar sets.

isoline: a line through points of equal value.

map design: the choices made in creating a map; decisions are generally based on the map's purpose, intended audience, and characteristics of the spatial data.

orientation: alignment, usually in reference to points of the compass.

qualitative: related to quality or kind.

quantitative: related to quantity, value, or amount.

scale: the relationship of the size of a feature on a map to its size in reality.

- ***bar scale:*** scale shown by a line, which is labeled to represent a stated distance.
- ***representative fraction scale:*** scale indicated by a ratio of one unit on the map to some number of the same units on the ground, for example 1/24,000.
- ***verbal scale:*** scale indicated by a phrase such as "one inch represents one mile."
- ***large scale:*** good for showing detail in small areas.
- ***small scale:*** good for showing a general view of a large area.

spatial data: information pertaining to a place linked to coordinates or other positional information.

thematic map: a map designed to show information on a single topic.

Answers to questions

On the Trail of Knowledge

Instruction 1. The lowest and highest magnitude values are 4.0 and 6.0, respectively. Mid-Atlantic earthquakes would be considered medium-magnitude.

Instruction 2. Symbols for plotting the data should be small, perhaps points. Earthquakes of magnitude 4, 5, and 6 might be shown in different colors.

Instruction 3. A descriptive title might be "Earthquakes of the Mid-Atlantic Ocean Floor, 1990." Thematic maps generally include the authors' names and the dates the map were made. A legend should include an example of each symbol used and an explanation of its meaning.

Instruction 4. The data plotted on this map reveal an S-shaped spatial pattern. Variations in magnitude seem to have a random pattern. The fact that two tsunami warning centers monitor the Pacific Ocean, while none monitors the Atlantic, indicates that magnitudes of earthquakes in the Pacific are expected to be much higher than those recorded in the Atlantic. (See the quotation from Magellan on the reverse of the poster.)

Maps With a Spin

Instruction 1.—County and municipal governments may be good sources of data.

Instruction 2.—Sort the data into categories defined by the class, such as economic data, transportation data, or land use data.

Instruction 4.—In evaluating data, groups should look for data that relate to their interests—data that may support their point of view. Groups may want to keep their ideas and decisions secret from opposing groups.

Instruction 5.—Final copies of materials for the town meeting should be neat and lettering should be large enough for presentation. Groups should plan their presentations: who will do what, when, where, and how. Arrangements for any special presentation plans (for example a slide presentation) should be coordinated with the moderator of the town meeting ahead of time.

Instruction 6.—Before the town meeting, decide who will act as moderator. As the meeting begins, restate the time limits and the order of presentation. After presentations and rebuttals, vote to decide which plan the town should recommend to the voters. If time is left, evaluate the role of maps in the presentations.

Exploration

Activities

Mapping the Third Dimension (making and using a stereoscope)

The Landscape of a Novel (mapping imaginary spaces)

Notes

This lesson explores the use of stereoscopic techniques and concept mapping, two mapping developments in this century. Photogrammetry and remote sensing have become the foundation of modern mapping. Computerized data collection, data base management, and data analysis have eliminated many time-consuming mapping tasks and expanded the capabilities of cartographers. Mapping techniques are being used in new, nongeographic applications.

Mapping the Third Dimension has students make a stereoscope and use stereoscopic aerial photographs to see a three-dimensional image. Students make a map of the image they see.

The Landscape of a Novel has students map places described in a story. Students organize and map the data in categories (i.e., roads, buildings, streams, names) much as digital map data are manipulated. After mapping the geographic setting of the story, the class makes a concept map of the plot.

Glossary—

concept map: a map-like illustration that shows relationships between concepts.

digital mapping: the making of maps using computerized data and procedures.

electromagnetic spectrum: the range of wavelengths or frequencies of electromagnetic radiation including gamma rays, visible light, and the longest radio waves.

image: likeness of an object or view; in remote sensing, a likeness produced without photography using an electronic spectral sensor.

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layer: in digital cartography, map data on a common theme manipulated separately from other types of data.

mosaic: a whole image or map made from parts from more than one source.

optics: the science that deals with light and closely associated phenomena.

perspective: the appearance to the eye of objects in respect to their relative distance and position; the technique of representing the spatial relationships of objects as they might appear to the eye.

positional accuracy: the accuracy of the location of a point.

remote sensing: the process of detecting and monitoring physical characteristics of an area by measuring its reflected and emitted radiation.

stereoscope: a device used to view overlapping photographs to obtain the mental impression of a three-dimensional image, or model.

Answers to questions

Mapping the Third Dimension

Instruction 4. The stereopair of photographs shows a view of the Colorado River in the Grand Canyon. Cartographers would use information acquired from surveying to measure elevations and distances (i.e., scale). For making the topographic map from this image use the following dimensions: top of peak A, altitude 5,600 feet; point B on the river, altitude 2,700 feet; horizontal distance from B to C, 1,000 feet.

The Landscape of a Novel

Instruction 2. Clear plastic may be available from an art supply store. Handling different kinds of information separately (i.e., as layers) mimics the methods of digital mapping and allows the cartographer to make various maps from the information. In combining layers for a frontispiece map, some or all layers may be used.

Instruction 4. In concept mapping, there are no right or wrong connections. Concepts can appear in more than one place or be connected to more than one other concept.

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Exploring Maps

Information

What else is here?

Maps are made for many reasons, and as a result, maps are of many kinds. Some made for general purposes may show roads, towns and cities, rivers and lakes, parks, and State and local boundaries. One example of such a versatile map, or ***base map***, is the 1938 topographic map of Oswald Dome, Tennessee. Other maps are much more specific, conveying information primarily on a single topic. The 1989 earthquake map of the United States is a good example of a special-purpose map, or ***thematic map***. Every map is made for a purpose and serves that purpose best.

The history of civilization has been illustrated by maps—battle maps by soldiers, exploration maps by empire builders, thematic maps by scientists. By modern convention, and for no scientific reason, modern maps are usually oriented with north at the top. But Al Idrisi's 1154 world map shows the Arabian Peninsula in the top center of the map, with south at the top. Contrast this map with the 1452 Leardo world map. Different societies in different places literally have different perspectives, which may result from differences in physical geography, language, religion, cultural values and traditions, and history.

Even within a culture, a time, and a geographic realm, maps can vary widely. This is because a map shows the cartographer's bias as well as the purpose. Maps are the result of conscious design decisions. Cartographers decide how to generalize and symbolize what they are trying to show. They select features (or themes) to show and omit other features. They often generalize the data, simplifying the information so that the map is easier to read.

In choosing the scale, mapmakers determine how large an area they can map and how much detail they can show. The selection of symbols (which can include lines, patterns, and colors) also affects the legibility, aesthetics, and utility of the map.

Cartography blends science and art. A beautiful map may become popular, even though it may be less accurate than a plainer version. Details of cartographic style affect how a map is perceived, and perception varies with perspective. In short, people understand the world differently, have different modes of expressing this understanding in maps, and gain different understanding from maps.

Geographic features can be shown at different sizes and levels of detail by using ***scale***. Maps include selected basic geographic information to provide ***context***. Every map has a purpose or theme. The ***map design***, which includes artistic aspects such as composition and balance, affects the success of the map—that is, its ability to communicate.

Scale is the relationship between the size of a feature on the map and its actual size on the ground. Scale can be indicated three ways. The ***bar scale*** is a line or bar that has tick marks for units of distance. The bar scale is especially important because it remains accurate when a map is enlarged or reduced. A ***verbal scale*** explains scale in words: "one inch represents 2,000 feet." The ***representative fraction*** is a ratio such as 1:24,000, in which the numerator (1) represents units on the map and the denominator (24,000) represents units on the ground; in the example of 1:24,000 scale, one unit (any unit—feet, millimeters, miles, etc.) on the map represents 24,000 of the same units on the ground.

Scale controls the amount of detail and the extent of area that can be shown. Scales can be described in relative terms as large scale, intermediate scale, and small scale. A ***large scale*** map (for example, the 1886 Sanborn map, originally at 1:600 scale) shows detail of a small area; a ***small scale*** map (for example, the 1877 geologic map of north-central Colorado, originally at 1:253,440 scale) shows less detail, but a larger area. (A comparison of representative fractions shows that 1/600 is larger than 1/253,440.)

The humorous 1893 quotation from Lewis Carroll illustrates this point by taking scale to the extreme. Some

small scale maps are regional ***compilations*** of more detailed maps, bringing information together for the first time at a common scale.

Context is information that serves to orient the map reader to the mapped place. As you look at the maps on the poster, you may look for familiar features (such as the "boot" of Italy) to identify the area shown. Geographic information that provides context can include coastlines, boundaries, roads, rivers and lakes, cities and towns, topographic features, place names, and latitude and longitude.

Distortion is another important aspect of context; every flat map of a curved surface is distorted. The choice of map projection determines how, where, and how much a map is distorted. It is important to understand the kind and amount of distortion on the map sheet. The typical mapping project now plots information on a base map, which shows where the place is and establishes the scale, orientation, context, and spatial distortion of the information to be mapped. The type and scale of the mapping project affect the choice of base map. Digital, or computerized, mapping frees the cartographer from some constraints imposed by a base map, because features can be readily selected or deleted, and the projection and scale can be changed easily.

A map's purpose is usually clear from its title and explanation, but other information (author, date, publisher, source of funding, etc.) hints at why and for whom the map was made. A knowledgeable map reader, recognizing that a map is both a simplification and a distortion of reality, will look for clues to the cartographer's purposes and biases.

The information collected for a mapping project is called ***spatial data***. Any object or characteristic that can be assigned a geographic location can be considered spatial data. Spatial data always include locations, but may also include values to be represented.

These two kinds of information are ***qualitative data*** (for example, schools, roads, rivers, States) and ***quantitative data*** (for example, altitudes, amount of precipitation, per capita income, population density). Qualitative data, while not numeric values, may be ranked, as in categories of roads or schools.

Quantitative data can be treated in many ways. The cartographer may first decide to ***generalize*** data. Several closely spaced points may be generalized to one symbol; features may be eliminated as map scale is reduced; questionable data may be eliminated where other data are sufficient.

Likewise, ***grouping*** of data can be done in different ways. Large ranges of numbers may be grouped with breaks at round numbers (for example, 10, 20, 30) or at statistical mean and standard deviation values; in this case, the individual points may be mapped in various colors or sizes to correspond with group values. Another way to group data is within geographic areas, using colors or symbols for areas, rather than symbols at each data location. Generalization and grouping dramatically affect the message the map presents by simplifying the data.

The success of a thematic map depends on ***map design***. Scientific maps like Edmund Halley's 1701 map of compass variations usually show only enough geographic data to orient the user, while emphasizing the content. Halley, for whom the comet is named, pioneered several cartographic techniques. The 1701 map introduced ***isolines***, lines of equal value, a technique now used on topographic and other kinds of maps. The 1886 Sanborn fire insurance map includes as much as its business purpose requires, but nothing more. Triangulation maps, such as the 1744 map of France, show the network of points and lines, in this case colorfully framed within national boundaries. The 1989 earthquake map of the United States indicates the relative hazard by a contoured and colored surface, which also shows State boundaries.

Activity I:
On the Trail of Knowledge

Plot the earthquake epicenter data (see page 5), on the base map of the North Atlantic ocean floor. Use different symbols or colors to characterize different values.

Time:

One 50-minute class period.

Materials:

- Earthquake data (page 5)
- Base map (page 5)
- Colored pens or pencils
- Ruler
- Scrap paper

Procedures:

1. Study the data to learn what information you have and to determine the range of values. This may be easiest to do by reorganizing the data in a new list or table. What are the lowest and highest magnitude values? Considering that the Richter scale of earthquake magnitude includes values from 0 to about 9, are mid-Atlantic earthquakes weak, medium, or strong?

2. Consider generalizing or grouping data to simplify the mapping. In other words, decide whether you need to map all points to see the pattern in the data. Decide on symbols to use in plotting the data. Consider making a sample plot of some data points to test symbol size, color, etc.

3. Plot data points by latitude and longitude coordinates on the base map. Use a ruler as needed to help estimate locations between latitude and longitude lines. Choose a descriptive title, and make a scale and legend for the map.

4. Discuss the pattern revealed from mapping the data. Discuss the fact that two tsunami warning centers monitor the Pacific Ocean, but none monitors the Atlantic. What does this imply about magnitudes of earthquakes in the Pacific Ocean? (Note that Magellan commented on the appropriateness of the name of the Pacific Ocean.)

Extension

Referring to the 1957 map of the ocean floor, and the quotation from Tharp's book, discuss this example of the process of scientific discovery.

Activity II:
Maps With a "Spin"

In teams of three or four students, research and map the effects of a proposed airport three miles outside town. Each team is to prepare a presentation based on a set of maps it makes. Teams will represent different points of view: town government, homeowner's associations, business interests, developers, and State or county government. Teams will emphasize different information. All teams must use the same data, but each team can decide how to generalize the data and map the patterns they want to present.

Time:

Three evenings of homework for steps 1-3.

Two 50-minute classes for steps 4 and 5.

One 50-minute class for step 6.

Materials needed for each group:

- Base map of your locality (several copies)
- Geographic data from which to select map topics
- Local newspapers
- Calculators
- Graph paper
- Colored pencils or markers
- Stapler

Procedures:

1. As a class, collect basic geographic data from various sources: government, local libraries, student observations, businesses, and other organizations. For example, zoning and development regulations, weather records, locations of landfills and other waste sites, data on land use (residential, farming, commercial, governmental, recreational), boundaries of school districts, locations of fire departments and fire hydrants, water supplies, pipelines and power lines, natural hazards (flood plains, landslides, earthquake risk zones), special scenic or historic sites, transportation features, wildlife refuges, and so on.

2. Sort the data by type: economic, climatic, demographic, and so on. Select data sets that are especially important for consideration in planning an airport.

3. Research local newspapers to identify interest groups active in local issues; briefly discuss issues in class to clarify the point of view of each group. Evaluate maps in newspapers. Do they have "spin?" Break the class into the working groups.

4. Evaluate data and sketch a few test maps. Select only the data that support your point of view or need for information. Remember the importance of good choice of color, attractive lettering, and other aspects of map design in presenting information.

5. Prepare the final copies of materials for a town meeting. Make final copies of maps; be sure each map has a legend and cites sources of information. Be able to defend your choice of map type, symbols, colors, and generalization or groupings of data. Write notes or a paragraph to briefly explain what each map shows; these will be your speaking notes for the town meeting.

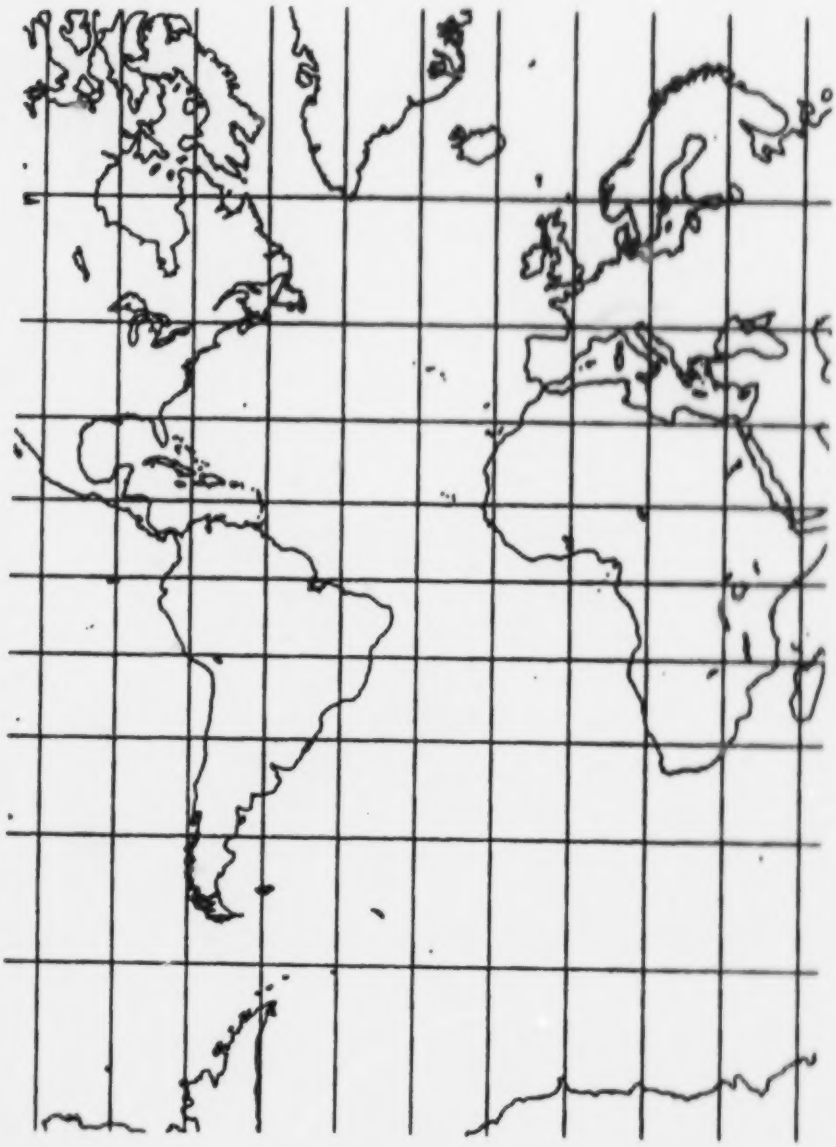
6. Have a class "town meeting" where the maps are presented and the issues are discussed. Allow each group 4 minutes to present its views, after which each group has 1 minute for rebuttal. The teacher or a student may act as moderator, keeping the meeting on time and on track.

Earthquake data for 1990

Area from latitude 45°N to 45°S, longitude 0°E to 45°W.

Note: Magnitudes are measured on the Richter scale, in which every 1 point difference in magnitude represents a ten-fold difference in energy released by an earthquake.

From U.S. Geological Survey, National Earthquake Information Center's global hypocenter data base.



Latitude	Longitude	Magnitude
21.77S	13.13W	4.7
32.14S	14.10W	4.4
30.73N	41.66W	4.6
27.13N	44.46W	4.7
33.65N	38.57W	4.8
6.44N	33.80W	5.1
33.74N	33.29W	4.8
13.50N	44.79W	4.3
7.37N	35.29W	5.7
17.20S	14.28W	4.6
0.54S	19.76W	4.6
14.64N	23.52W	4.2
8.47N	37.50W	4.7
3.62N	31.55W	4.7
1.21S	24.42W	5.1
38.37S	16.59W	5.0
26.71N	44.61W	4.5
0.94N	26.53W	4.9
33.63S	13.41W	4.6
28.45N	43.74W	5.3
44.75S	15.60W	4.8
4.52S	12.28W	5.1
0.07S	17.52W	5.8
44.62N	28.38W	4.8
4.37S	10.78W	4.8
0.54S	14.27W	4.8
39.91N	29.68W	4.3
37.10N	33.04W	4.4
7.14N	34.20W	4.8
0.96N	28.81W	5.2
35.43N	35.65W	6.0
17.70S	13.25W	5.1
9.53N	40.60W	4.9
13.97S	14.51W	5.0
41.31N	29.35W	4.5
27.72N	44.08W	4.9
0.26S	20.89W	4.8
24.89S	13.58W	4.6
43.65S	16.16W	6.3
0.06S	16.67W	5.0
7.62N	36.03W	5.0
35.21S	17.13W	4.9
8.26N	38.51W	4.0
43.73N	28.66W	5.7
2.16N	30.74W	4.7
0.98N	26.70W	4.5
42.55S	16.14W	5.4
21.03S	11.48W	4.9
1.13S	24.44W	4.9

BEST COPY AVAILABLE

Glossary:

base map

compilation

context

distortion

generalization

grouping

isoline

map design

orientation

qualitative

quantitative

scale

- bar scale
- representative fraction scale
- verbal scale
- large scale
- small scale

spatial data

thematic map

Additional activities:

Evaluate news coverage of a local development issue that uses maps. What kinds of maps are being used? Do the maps appear biased? How? Do different news organizations present different opinions, biases, or maps with different information? What seem to be the most effective ways to affect public opinion with maps?

Invite a geologist to class to talk about plate tectonics, perhaps looking at California earthquakes or the geologic story of the Hawaiian Islands, the Himalayas, or a nearby National Park.

From the reverse of the poster, select two quotations that seem especially pertinent to this activity sheet, and write an essay that discusses the ideas of both writers.

Recommended reading:

Monmonier, Mark. *How to Lie with Maps.* Chicago: University of Chicago Press, 1991.

Wood, Denis. *The Power of Maps.* London: The Guilford Press, 1992.

U.S. Department of the Interior
U.S. Geological Survey

Exploring Maps

Location

How do we know where we are?

For the most part we sense our surroundings visually. We may see canyons, rivers, sand dunes, mountain peaks, schools, roads, or other ***landmarks***: we understand our surroundings as a collection of visible features.

We also think of places in terms of other places. For example, you know where you live relative to friends' houses, school, and so forth. From downtown to the boondocks, distances and directions to other significant places form part of our understanding of places in the world. In a larger way, we have also come to understand the relationship between our surroundings and the Sun, Moon, and stars by carefully observing the changing sky.

A great number of devices have been invented to measure places. The first tools, invented thousands of years ago, were simple gadgets: the level, the sight, the measuring chain. Mathematicians developed geometry to describe shapes and relationships of objects in space. The ***magnetic compass***, the ***sextant***, the telescope, the ***theodolite***, the ***planetable***, and the ***marine chronometer***, used in combination with mathematics, have greatly increased mapping accuracy.

Developments in mapping continue today with advances in computer hardware and software, lasers, and satellites, which carry ***remote sensing*** devices around the Earth and to distant places in the solar system.

Technological innovation and the advancement of science have gone hand in hand. The development of agriculture eventually led to land ownership, which led to ***surveying*** and taxes.

In the third century B.C., the Greek astronomer and mathematician Eratosthenes used observations of shadows and distances to calculate the circumference of the Earth. His calculation, about 25,000 miles, was accurate to within 500 miles.

Observations of stars, planets, and other objects in the sky, meanwhile, were being recorded with great accuracy (as shown, for example, on the 1193 Suchow ***Planisphere***), changing people's understanding of the relationship of the Earth and the heavens.

Local measurements of distances and direction provided detailed information about small areas; little by little, this information was compiled on less detailed maps of larger areas (for example, the 1109 Beatus map, the 1452 ***Mappa Mundi***, and the 1502 Cantino Planisphere), presenting broader views of the Earth as it was thought to be. Many of these old maps, however, also include conjecture and decoration, without distinguishing between the known and the unknown.

As mapping entered the Renaissance, European navigators used the magnetic compass in navigation, developing ***portolan charts***. In the late 1600's, surveyors improved accuracy by using Galileo's telescope and a technique called ***triangulation***. In this process, the location of a new point is determined by measuring a distance between two known points and measuring angles from each end of this line to the new point.

Although solar observations were useful for measuring distances north and south ***(latitude)***, accurate measurement east and west ***(longitude)*** was not possible until 1765, when the marine chronometer was introduced. This was the first precise portable clock unaffected by the rocking motion of ships.

Beginning in the 19th century, photography and the aerial viewpoint revolutionized mapping. By the 1920's, aerial photographs were found to be excellent mapping tools, especially when viewed through the stereoscope, revealing a three-dimensional image. ***Photogrammetry*** and remote sensing from satellites and airplanes have extended the mapper's view to distant planets and beyond.

Activity I:
Tools of the Ancients

This pair of exercises introduces students to two tools that make observations of the Sun. Each exercise is a group activity to help students see how tools were used to collect geographic data. These new data contributed to a better understanding of the relationships between places.

How Columbus Determined His Latitude

Columbus used navigational tools to determine his ship's position, keeping track of his progress on charts of the seas or world maps like the 1482 map by Ptolemy, the best at the time. Columbus determined the latitude of his position by measuring the height of the sun above the horizon. (He determined Longitude by ***dead reckoning***.)

Time:

One 50-minute class period.

Materials for each group of four students:

- Drafting triangle or ruler
- Protractor
- String (12 inches long)
- Tape
- Paper clip
- Quarter
- Notebook and pencil

Procedures:

1. Make an instrument to observe the height of the Sun above the horizon, as follows:

a) Tape a protractor to the side of a triangle, aligning one outside edge of the triangle with the zero point and 90-degree mark on the protractor, as shown in illustration A.

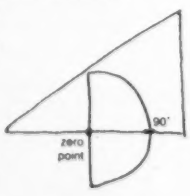


Illustration A

b) Clip the paper clip onto the quarter and tie the paper clip to the end of the string.

c) Tape the string to the protractor so that it hangs freely from the zero point, as shown in illustration B.

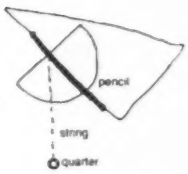


Illustration B

d) Align the pencil with the zero point and 90-degree mark on the protractor and tape it in place, as shown in illustration B.

2. Take observations when the Sun is highest in the sky, which is generally within a half hour of noon. The analemma (illustration D) shows the variation between solar noon and noon according to standard time on the clock. If you are in a time zone observing daylight savings time, the Sun will be highest an hour later.

3. To take a reading on the Sun with this instrument, ***do not look directly at the sun***; observe the shadow of the instrument. Stand on pavement or another smooth surface (not grass). One student holds the instrument a few feet above the ground so that the pencil points directly at the Sun and the string hangs freely next to the protractor.

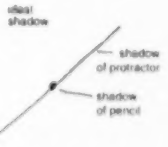


Illustration C

Looking at the shadow on the pavement, the student moves the instrument until its shadow appears as a line (from the triangle and protractor) with a dot (from the pencil), as shown in illustration C. The other students take turns reading the angle between the string and the 90-degree mark on the protractor, and recording this angle in their notebooks. The readings will probably differ, so the group compares them and settles on the best value. It may be best to discard the highest and lowest readings and average the other values.

4. To determine the latitude, adjust this number, representing the angle, to correct for the tilt of the Earth's axis. The adjustment changes with the seasons. Use the analemma (illustration D) to determine the correction needed. For observations in the Northern Hemisphere, the Sun appears lowest in the sky in late December; at this time, add 23.5 degrees to the reading; at the summer solstice in June, subtract 23.5 degrees from the reading. Intermediate adjustments for readings between these dates can be estimated from the analemma.

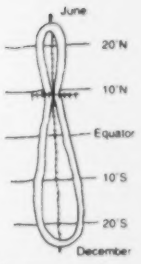


Illustration D

Extensions:

1. Construct a scale model of the solar system showing relative sizes of planets and distances from the Sun.

2. Discuss what might have happened had Columbus used Eratosthenes' measurement of the Earth's circumference.

3. Look more closely at the analemma. Why does the length of the day vary?

Local time and "Grinnage time"

In the quotation from *Tom Sawyer Abroad*, Tom tries to explain to Huckleberry Finn that time differs around the globe. Local noon time once was determined by measuring the highest point in the Sun's daily arc, so that local time varied from east to west. In the late 1800's, time zones were established to help standardize time. The sundial shows the relationship between local time and standard and daylight savings time.

Time:

15 minutes preparation (steps 1-3).
Nine 10-minute observations, mostly concentrated around noon. 15-30 minutes discussion after observations are made.

Materials for each group of four students:

- One pole about 3 feet long to hammer into the ground or a free-standing pole with a pointed top (you can use an old radio antenna or a gate post with a pointed top)
- A "do not disturb" sign to mark the experiment area
- String about 15 inches long with a weight at one end
- Nine 1- by 2-inch pieces of scrap paper labeled with the observation times
- Nine stubby pencils
- Protractor
- Measuring stick or tape
- Notebook and pencil

Materials in the classroom:

- Blackboard on which to draw a scale model of your sundial

Procedures:

1. Working as a class, choose a flat spot where the Sun will not be blocked during your observation period. Beware of shadows from trees and buildings.

2. Set up the pole, being careful to make it vertical; using the string with the weight on the end as a plumb bob, check to be sure the pole is vertical. The pole should be placed firmly enough to remain in position throughout the day. Measure the height of the pole and record the measurement in the notebook.

3. Label the scraps of paper with the times you will take observations, such as at 10, 11, 11:20, 11:40, 12, 12:20, 12:40, 1, 2. Plan observations to be as symmetrical as possible around local noon. Note that during daylight savings time, local noon is delayed one hour. Find your location on a map that shows time zones; the closer to a time zone boundary, the greater the difference between local noon and noon according to the clock.

4. Divide the class into groups of three to take observations. A pair of students marks the position of the end of the pole's shadow. One student (the observer) pokes a pencil stub (point down) through the piece of paper labeled with the time and holds it on the ground such that the point of the pole's shadow falls on the hole where the pencil goes through the paper. The second student (the recorder) verifies the position, and the observer pushes the pencil in the ground.

The third student (the measurer) then measures the length of the shadow from the base of the pole to the pencil; the recorder records this in the notebook with the time. The measurer then uses the protractor to measure the angle between the shadow and its previously observed position, which the observer marks by stretching the string from pole to respective pencil; the recorder writes this value in the notebook.

Be careful during observations not to move the pole. Observations and measurements should be made quickly but carefully; 3 minutes should be enough time.

5. Back indoors, record the various measurements on the blackboard on a scale drawing of the sundial.

6. After your last observation of the day, ask the class to determine the time when the Sun was at its highest. This is local noon.

7. Discuss the difference between local noon as measured by the sundial and as indicated by the clock.

Extensions:

1. Notice that the sundial becomes a compass at local noon—that is, the shadow at local noon points to the geographic north pole. Using a compass, find the difference between geographic north and magnetic north. Experiment with the magnetic compass and map use. Discuss orienteering. (Information is available in such publications as the *Boy Scout Handbook* and the USGS leaflet "Finding Your Way With Map and Compass.")

2. Using geometry, calculate the width (in degrees) of a time zone. With this information calculate your longitude by comparing your time with time in Greenwich, England.

Activity II: A Place in Time

In groups of two, select a place to study, and note how it has changed over time. Choose an old city near you or a famous place anywhere.

Time:

Two 50-minute class periods.

Materials for each pair of students:

- Books, articles, maps, photographs, and other information about the history of your place
- Continuous-feed computer paper (about 6 feet long)
- Scissors
- Tape
- Markers

Procedures:

1. Study the history of a place. Find out who settled there, when, and why. How did they make a living? Who else did these people have contact with? As time passed, when and how did the place change? When, why, and how did the population grow? How did the relationship between this place and the surroundings change? How did this place function in the context of the immediate area and in the world? How did this function change? How did world events affect this place?

2. Make a timeline on which to record information you collect about the place from its founding to the present. Summarize the history of the place by dividing its history into periods and labeling the periods.

3. Illustrate the timeline with sketches or photographs from newspapers, magazines, or other sources.

4. On a base map of the area, sketch a map of the place for each period.

5. Display timelines and review them for aspects of effective presentation: color, lettering size, organization, size and style of maps, etc.

Glossary:

dead reckoning

Greenwich time

landmark

latitude

longitude

magnetic compass

mappa mundi

marine chronometer

photogrammetry

planetable

planisphere

portolan chart

remote sensing

sextant

surveying

theodolite

triangulation

Additional activities:

1. Invite a surveyor to demonstrate today's tools to the class.

2. From the reverse of the poster, select two quotations that seem especially pertinent to this activity sheet, and write an essay that discusses the ideas of both writers.

Recommended reading:

Boorstin, D.J. *The Discoverers.* New York: Random House, 1983.

"Finding your way." *Boy Scout Handbook, tenth edition.* Irving, Texas: Boy Scouts of America, 1990, 179-211.

Finding Your Way with Map and Compass. U.S. Geological Survey leaflet, 1989.

Morrison, Phillip, and Morrison, Phylis. *The Ring of Truth.* New York: Random House. 1987.

Wilford, J.N. *The Mapmakers.* New York: A.A. Knopf, 1981.

U.S. Department of the Interior
U.S. Geological Survey

Exploring Maps

Navigation

How do we know where we're going?

Travel depends on the ancient skill of navigation—the ability to find a way from one place to another and back. Columbus was not sure how far he had to go. In his journal he recorded his latitude observations and estimates of distance traveled underreporting this distance to the crew, "lest the trip be long."

Polar explorers depended on navigational data for survival, as well as success. Sir Ernest Henry Shackleton, who attempted to reach the geographic South Pole several times between 1902 and 1922, was once marooned on a moving ice shelf and his ship was crushed; Shackleton's survival depended on the latitude and longitude observations that described the motion of the ice.

Travelers on land need somewhat different information from those at sea. Travelers on solid ground can follow circuitous routes between important landmarks using schematic maps (for example, the A.D. 250 Peutinger map). Seagoing voyagers need more from their maps, as the ocean moves beneath them and the wind and waves push the ship across a featureless surface (for example, the A.D. 1502 Cantino Planisphere, a portolan chart). Sailors on the open sea have kept track of absolute position using the only reference points they have: the Sun and stars.

The globe is the best way to show the relative positions of places, but a globe that can fit in a ship's cabin cannot show the detail needed for navigation. Flat maps distort the placement of features, but can show great detail and are portable.

The transformation of map information from a sphere to a flat sheet can be accomplished in many ways, called projections. Mapmakers have invented projections that show distances, directions, shapes, or areas as they are on a globe, at least partially. Different projections have different advantages and disadvantages.

Orthographic projections, for example, show shapes as they appear when the globe is viewed from space. Equal-area projections do not distort the size of areas but do distort their shapes. Conformal projections are those on which the scale is the same in any direction at any point on the map.

Many projections retain one geometric quality, and a few retain more than one quality, but no single projection can accurately portray area, shape, scale, and direction. (A map projections poster available from the USGS Earth Science Information Center illustrates the features of the most common map projections.)

The Mercator projection was designed by Flemish cartographer Gerardus Mercator in 1569 to show compass directions as straight lines in all directions from all points on the map. This was an important breakthrough in mapping. Using a Mercator projection, navigators could draw a straight line to a destination, sail in that direction, and expect to reach it, allowing for the effects of ocean currents and other factors.

Mercator made longitude lines parallel and increased the distance between latitude lines away from the equator. As a result, extreme northern and southern areas appear enlarged. For example, Greenland looks larger than South America, although South America is eight times as large in reality. This distortion at high latitudes (north and south) also makes the distances appear larger than they are. Even with these disadvantages, this projection remains one of the most commonly used.

Activity I: Make a Mercator Projection

Follow the directions below to make a close approximation of the normal Mercator projection. A few activities with the map are included to demonstrate the important characteristics of this projection.

Time:

One 50-minute period for steps 1-10.

After photocopying in step 11, one 50-minute period for steps 11-14.

Materials per person:

- Protractor
- Compass
- Ruler
- Two sheets of 11 x 17 inch paper
- Transparent tape
- Sharp pencil
- Fine point pen, preferably black

Procedures:

1. Tape the two pages together along the 17-inch sides and orient the paper as shown in illustration A, with the tape on the reverse side.

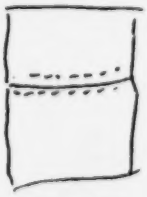


Illustration A

2. The joint between the two pieces of paper will be the "equator." Lay the protractor on the paper with the flat side on the left. Place the zero point and the 90-degree mark on the equator (see illustration B). Use the compass to draw a semicircle with a 6-inch diameter, flat side on the left. Mark the center (the zero point, Z) on the diameter. IMPORTANT NOTE: *Make all marks lightly in pencil, unless otherwise instructed.*

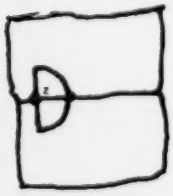


Illustration B

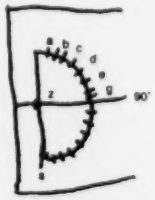


Illustration C

3. Using a protractor, mark every 10 degrees around the semicircle (see illustration C). Starting at the top, label these points A, B, C, ..., S.

4. Beginning at Z, measure left along the equator 2/5 of a radius (in this case, 1.2 inches) and mark a new point, T, as shown in illustration D.

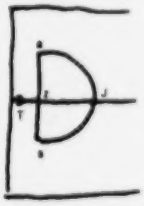


Illustration D

5. Using the protractor, draw the westernmost line of longitude perpendicular to the equator and tangent to the original semicircle at point J (see illustration E).

Illustration E

6. Set the spacing of the lines of latitude as follows: With the left end of your ruler on point T, align the right side to point I on the semicircle; mark where this line (TI) intersects the westernmost longitude line. Beginning again at point T, mark points on the westernmost longitude for lines through points H, G, F, E, D, and C (see illustration F). Each point marks 10 degrees of latitude.

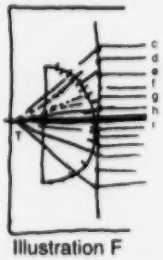


Illustration F

7. Draw latitude lines parallel to the equator through these new points. To make the latitudes parallel, measure the distances between marks on the westernmost longitude line; copy these measurements and mark equivalent points on the easternmost longitude line. Connect pairs of points (a western and an eastern), preferably beginning closest to the equator.

8. Repeat steps 6 and 7 for latitudes south of the equator. Notice that on this projection, lines of latitude are parallel and spacing between them increases away from the equator. Latitudes 90° N and 90° S cannot be shown on a Mercator projection, because they are infinitely far from the equator (although this approximate construction does not show this).

9. Set longitude lines as follows: Measure east 0.5 inches from the westernmost longitude and make a mark on the equator. This represents 10 degrees of longitude. Repeat this step 17 more times, and you will have 180 degrees of longitude. From each point on the equator, use the protractor to draw a perpendicular line. On the Mercator projection, longitude lines are parallel and equally spaced, as shown in illustration G.

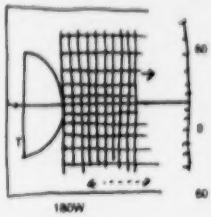


Illustration G

10. At this point, the map covers only half the planet *(a hemisphere)*. Carefully trace this grid in ink.

11. To map the entire Earth, make two copies of the original and join the copies along the one's easternmost line of longitude and the other's westernmost (see illustration H). Lines should connect across the copies. These two lines both represent the Prime Meridian, the line of 0 degrees longitude.

12. Label the latitude and longitude lines along the right and bottom of the map. The equator is 0 degrees latitude, and latitude values increase in increments of ten to the north and south. The westernmost longitude line is 180 degrees W; longitude values decrease in increments of ten to 0

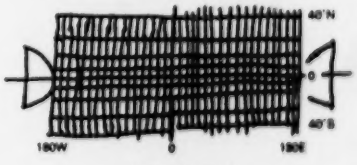


Illustration H

degrees at the Prime Meridian, and increase again to 180 degrees at the eastern edge of the map (see illustration H). This map approximates the characteristics of the Mercator projection within about 2 percent.

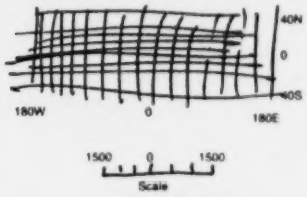


Illustration I

13. Make a bar scale in the margin below the map. A bar scale is commonly centered below the map, in this case, below the Prime Meridian (see illustration I). To determine the scale at the equator, divide the Earth's equatorial circumference (24,902 miles; 40,075 kilometers) by 360 degrees; therefore, each degree of longitude and latitude at the equator equals about 69 mi (about 111 km). Ten degrees of longitude at the equator (about 690 miles) is represented by 0.5 inch on the map; one inch represents 1,380 miles. Draw a line representing 3,000 miles (about 5,000 kilometers).

14. Sketch the outlines of the continents as shown on other maps available in the classroom. Plot the course between Columbus' home port and destination; your home town and the western coast of Africa; and the route of an oil tanker from Kuwait to Tokyo, Japan. Notice that you cannot plot polar explorations.

Extension:

Obtain a variety of world maps from the school library and compare the properties of the projections. Various atlases may prefer different projections. Which seem to be the most popular projections for world maps? For detailed maps?

Activity II: In the Wake of Lewis and Clark

In groups of three or four study the route of Meriwether Lewis and William Clark's travels and the important events in their journey.

Time:

One week (homework) to scan the journals of Lewis and Clark.

One 50-minute class period per step.

Materials per student:

- Copies of journals of Lewis and Clark (see bibliography)
- Notebooks and pencils

Materials per group:

- Highway maps of the western United States.
- Information about Lewis and Clark's expedition (see sources listed below)
- Colored markers
- Map showing State and national boundaries in 1804 and the Louisiana Purchase

Procedures:

1. List places visited by Lewis and Clark and categorize them as natural landmarks, native villages, sites of special events, pioneer outposts, etc. Mark these sites on a map of the western United States. Mark State boundaries and the western boundary of the United States as they were before the Louisiana Purchase.

2. Referring to Lewis and Clark's report, summarize their weekly progress, marking the map as well as possible. Use symbols for special places: important natural landmarks, the place where they met Sacagawea, major camp sites, major obstacles, sites where friendly natives provided important help, places where they suffered especially bad weather, places where they changed from river to overland travel, etc. Indicate the boundaries of native cultures along their route.

3. Plan an imaginary trip along part of the route of Lewis and Clark. How far can you travel in a week? What obstacles will you face? Where will you replenish your supplies? What will you take? How many are in your party, and what are each one's responsibilities? How much will this cost? How will you pay for the trip? What can you accomplish on this trip?

Extensions:

Keep a journal as if you were with the Lewis and Clark expedition for one week. Include feelings, experiences, discoveries, people met, etc. You may refer to events described for the time period selected.

Sources of further information about Lewis and Clark:

Lewis and Clark Trail Heritage Foundation, Inc., P.O. Box 3434, Great Falls, Montana 59403

Lewis and Clark National Historic Trail, National Park Service, 700 Rayovac Drive, Suite 100, Madison, WI 53711

Lewis' and Clark's journals, their report, and secondary descriptive writings, which your local librarian can help you locate.

Additional activities:

1. Read a diary of another explorer or pioneer and write a two-page essay comparing this journey with that of Lewis and Clark.

2. Have a travel agent visit the class and discuss planning for a trip to a different continent, and how the travel business has changed in the past 40 years.

3. From the reverse of the poster, select two quotations that seem especially pertinent to this activity sheet, and write an essay that discusses the ideas of both writers.

Recommended Reading:

Biddle, Nicholas, ed. *The Journals of the Expedition under the Command of Capts. Lewis and Clark.* New York: The Heritage Press, 2 vols., 1962.

Map of the Conterminous United States Showing Routes of the Principal Explorers from 1501 to 1844.... U.S. Geological Survey United States map. 1983.

Map Projections. U.S. Geological Survey poster. 1992.

Maps of an Emerging Nation—The United States of America, 1775-1987. U.S. Geological Survey National Atlas Map. 1987.

Snyder, J.P. *An Album of Map Projections.* U.S. Geological Survey Professional Paper 1453, 1989.

U.S. Department of the Interior
U.S. Geological Survey

Exploring Maps

Exploration

Where do we go from here?

The changes in map data collection and display that have occurred in the 20th century are comparable to the change from pedestrian to astronaut. Information that used to be collected little by little from ground observations, can now be collected instantly by satellites hurtling through space, and recorded data can be flashed back to Earth at the speed of light. Remote sensing devices collect data from parts of the ***electromagnetic spectrum*** outside the narrow band of visible light. Gathering gravity, magnetic, and other data takes us beyond the electromagnetic spectrum, beyond our five senses into new territories, all of which can be mapped.

Fundamental to ***remote sensing*** is the practice of photogrammetry (measuring from photographs). Photogrammetry is built on developments in many fields of science and technology. Leonardo da Vinci (1452-1519), was perhaps the first to write about the theories of ***optics***. Italian and German painters and scientists explored the laws of ***perspective*** in the early 1500's; these were enlarged upon in a 1759 treatise by Henry Lambert, a French mathematician, who established the geometric foundation of photogrammetry. ***Stereoscopes*** that allowed two photographs to be viewed simultaneously to create a three-dimensional view were first demonstrated in 1851, creating a source of amusement and education. When photography went airborne, first from balloons and later from airplanes, stereoscopic cameras were used to make topographic maps.

Developments in remote sensing are founded on centuries of scientific work. In 1514, Nicholas Copernicus, a Polish priest, suggested (anonymously at first) that the Sun was the center of the solar system, an act of heresy at the time, although it explained the observed motions of the planets. Galileo Galilei's 1609 telescope demonstrated the importance of lenses for magnification. In 1687, Isaac Newton's *Principia Mathematica* was published, establishing the basic laws of motion and gravitation; Newton—and simultaneously Gottfried Wilhelm von Leibnitz, in Germany—developed the calculus, which helped explain the mathematical principles behind elliptical orbits.

Engineering and computational advancements during the industrial revolution and the spread of computers have taken mappers from ships to spaceships. Developments in aeronautics and rocketry in the early 1900's, and in lasers, computers, and satellites in recent decades, have given cartographers powerful new tools. The 1936 Oswald Dome ***mosaic*** of aerial photographs and the 1937 topographic quadrangle of the same area were part of a test of the use of stereoscopic aerial photographs in topographic mapping. Such photogrammetric methods were incorporated into routine topographic map production in the United States before World War II.

Since the late 1960's, map information has been collected, stored, and used in digital form. Satellites carrying remote sensing devices collect long strings of numeric data and transmit the data to receivers on Earth. The data are then reconstructed into digital ***images*** that look like photographs.

Cartographers now can gather spatial data and make maps faster than ever before—within hours—and the accuracy of these maps is excellent. Moreover, ***digital mapping*** enables mapmakers to experiment with a map's basic characteristics (for example, scale or projection), to combine and manipulate map data, to transmit entire maps electronically, and to produce unique maps on demand.

Geographic information systems (GIS) are computer systems that store, manipulate, and display geographic information in ***layers***, sets of data that

can be combined with other layers or manipulated and analyzed individually. Results can be seen instantly on a computer screen, in some cases replacing the need for paper maps, freeing the cartographer to experiment with changes in the base map or in the spatial data. In addition to the information content, the map scale, symbols (points, areas, and line styles), colors, type, and overall layout can be changed quickly, greatly speeding the process of mapping.

For all the benefits this technology offers, however, there is greater danger of cartographic abuse now that powerful mapping tools are in inexperienced hands. Different kinds of data are not always collected at the same scales; data analysis is only as objective as the analyst; display techniques control the information emphasized on a map. Now, more than ever before, some maps may mislead.

Positional accuracy of information is being further refined by the Global Positioning System (GPS), the basis of which is a set of satellites that orbit about 12,000 miles above the Earth. Portable GPS receivers on Earth receive the signals from GPS satellites above the horizon and calculate absolute position to accuracies far better than those on existing maps of most of the globe. The process is basic triangulation, but the new tools provide much greater precision.

Mapping technologies are being used in many new applications. Biological researchers are exploring the molecular structure of DNA ("mapping the genome"), geophysicists are mapping the structure of the Earth's core, and oceanographers are mapping the ocean floor. Computer games have various imaginary "lands" or levels where rules, hazards, and rewards change. Computerization now challenges reality with "virtual reality," artificial environments that simulate special situations, which may be useful in training and entertainment.

Mapping techniques are being used also in the realm of ideas. For example, relationships between ideas can be shown using what are called ***concept maps***. Starting from a general or "central" idea, related ideas can be connected, building a web around the main concept. This is not a map by any traditional definition, but the tools and techniques of cartography are employed to produce it, and in some ways it resembles a map. Indeed, our traditional definition of a map is strained when we consider songs of aboriginal storytellers as maps. This reinforces our recognition that maps are many things to many people, and mapping transcends cultures and the ages.

Activity I: Mapping the Third Dimension

Make a stereoscope. Great advances in mapping in the 20th century were based on the three-dimensional image visible in the stereoscope. In this activity, students work in pairs to construct a simple stereoscope. A pair of stereo photographs is included to use to view a three-dimensional image.

Time:

One 50-minute period for step 1.

30 minutes for remainder of the activity.

Materials for each pair of students:

- One cardboard box (an empty copier-paper box works nicely)
- Knife for cutting the box
- Two locker mirrors (durable, light weight, about 4 by 5 inches)
- Ruler
- Transparent tape
- Overlapping (stereo) aerial photos (enclosed)

Procedures:

1. Make the stereoscope as follows.

a) Remove the top of the box, leaving the box at least six inches deep.

b) Cut the box in half along the longer dimension (see illustration A) and set one half aside.

Illustration A

c) Place the half of the box (let's call this the "frame") in front of you so that you are looking into it. Along the back and front edges of the bottom panel, measure half the distance between the left (L) and right (R) end panels. Mark these points C1 and C2 and connect them with a line (see illustration B). Measure the height of the back panel of the frame (H). Set the frame aside temporarily.

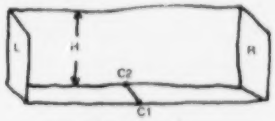


Illustration B

d) Using another piece of the original box, cut a prism-shaped piece that has a 90-degree angle (see illustration C). The two sides (S) of the prism that meet at the 90-degree angle must be the same size, one inch wider than the locker mirrors. The long dimension of the prism need not be longer than the value H.

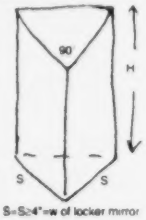


Illustration C

e) Attach the prism to the frame (see illustration D). Orient the prism so that the edge with the 90-degree angle is on the center line (C1-C2) and is pointed at the open side of the frame. The sides of the prism should be against the back panel of the frame, and the distance (D) between the sides of the prism and the end panels should be equal.

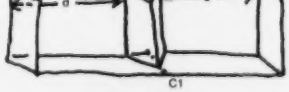


Illustration D

f) Tape the mirrors to the prism, resting them on the bottom panel of the frame, as shown in illustration E. Mirrors should meet at the 90-degree angle. This completes the stereoscope.

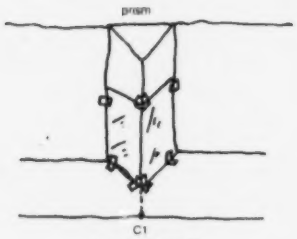


Illustration E

2. Using paper clips, attach the enclosed stereo photographs to the ends of the box, being careful to position them so that the

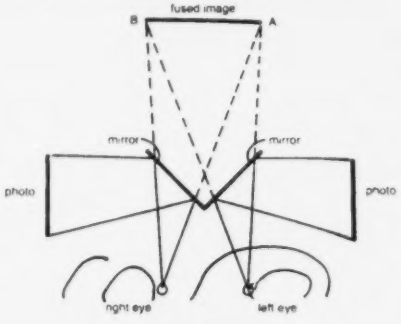


Illustration F

right eye sees the area of overlap in the right mirror and the left eye sees it in the left mirror.

3. Position the stereoscope so that both photographs are illuminated equally.

4. Look straight at the near edge of the mirrors from about a foot away (see illustration F). Tips for seeing the three-dimensional image: As you look for the stereoimage, try closing first one eye and then the other. Choose a distinctive feature and find it on both photographs. As you look, keep one image fixed and move the other image slightly to make the images of a distinctive feature on the two photographs come together. The three-

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dimensional image of the whole scene may suddenly appear (and perhaps disappear). Once you see the stereoimage, it is generally easier to see it again.

5. As a class, discuss how your brain constructs a three-dimensional image from the two, two-dimensional air photos. Photographs are taken sequentially along a flightline so that adjacent photographs overlap by about 60 percent. The left photo shows the perspective from the left camera station, and the right photo shows the perspective from the right camera station. Thus, your left eye sees the image from a different perspective from the right eye. The brain fuses the two images so that you see the entire area of overlap in three dimensions.

6. In this exercise, the three-dimensional image in your brain exaggerates the vertical relief; the slopes look steeper and buildings look taller on the stereo image than they are. This vertical exaggeration is a function of the geometry of the camera and the altitude of the camera when the photographs were taken. Vertical exaggeration, which can be useful in topographic mapping, can be quantified (or even eliminated) by photogrammetric mapping instruments. Judging by the vertical relief in the stereo image you see, sketch a topographic map of the area of overlap; select a contour interval and make the map at the same size as the stereo image.

Activity II: The Landscape of a Novel

As an individual or class exercise, use the geographic information in a book and map the places described. The book can be fiction or nonfiction, but should not be too long or involved. This activity develops the ability to collect data, envision spatial features, and design a map.

Time:

One 50-minute class period (after reading a book).

Materials:

- Notebook (for each student)
- Scrap paper
- A few sheets of blank paper or transparent mylar
- Chalkboard or flip chart

Procedures:

1. On scrap paper, list the kinds of features you will be mapping, such as towns, buildings, houses, rivers, lakes, roads, and airports.

2. On paper or clear plastic, draw maps of each separate layer. Include place names, scale, latitude, and longitude. Combine the layers (redrawing if necessary) to create a generalized view that could be used as a frontispiece for the book.

3. Write a short essay discussing how geography affected the events in the book. Note how the new frontispiece might affect a reader's impression of the book.

4. On a chalkboard map the plots and subplots of the book using concept mapping (see example in illustration G); start from any central story line (from any point in the book) and try to fill the space available.

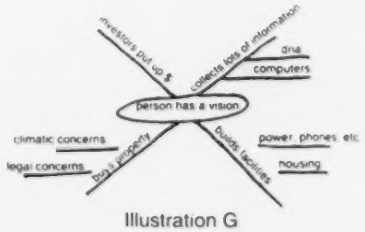

Illustration G

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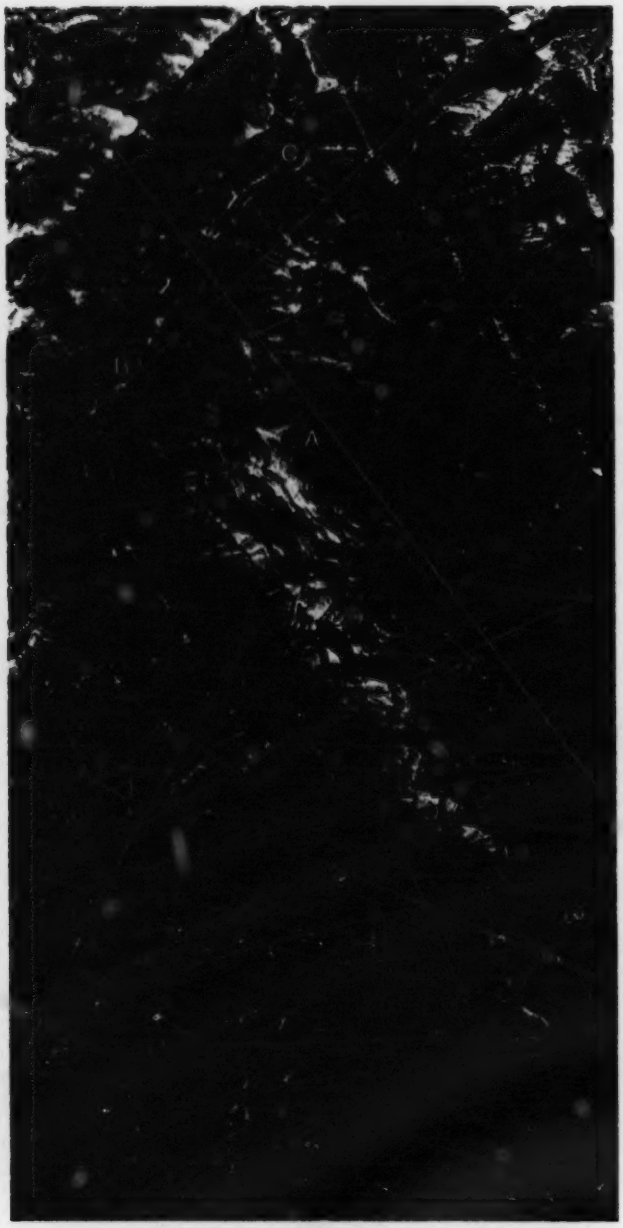

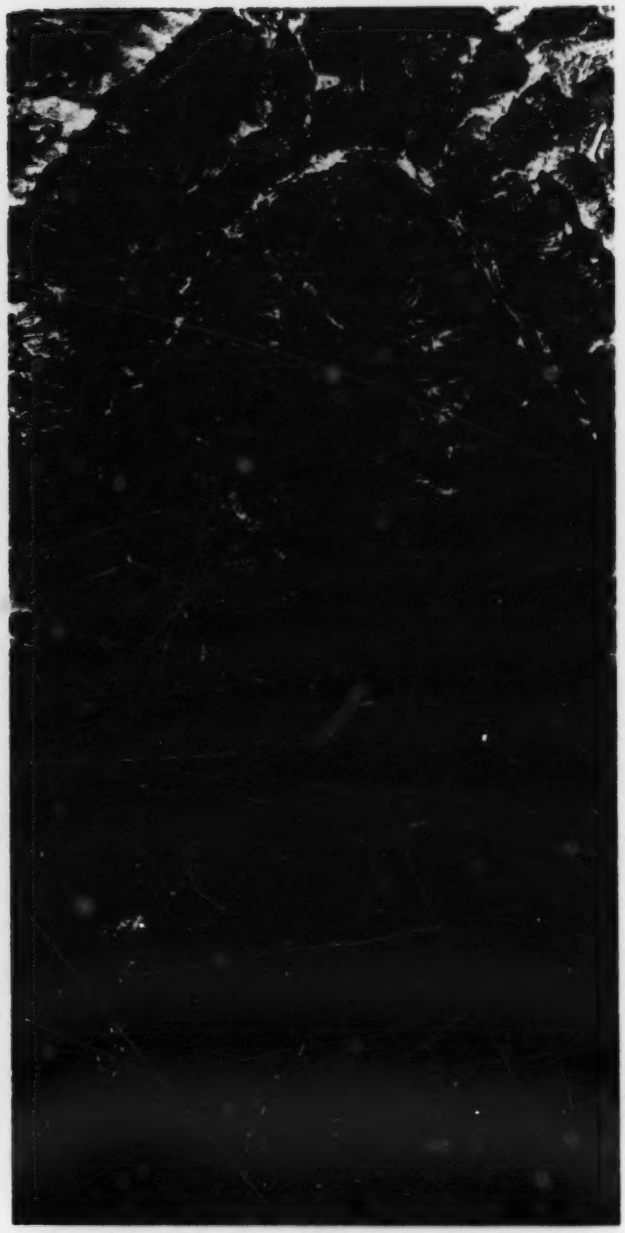

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Glossary:

concept map

digital mapping

electromagnetic spectrum

image

layer

mosaic

optics

perspective

positional accuracy

remote sensing

stereoscope

Additional activities:

Visit a local government agency or private mapping organization for a demonstration of its mapping operation. If possible, visit a GIS (geographic information system) facility.

Invite an optometrist to class to discuss the physics behind the instruments used in a typical vision test.

From the reverse of the poster, select two quotations that seem especially pertinent to this activity sheet, and write an essay that discusses the ideas of both writers.

Recommended reading:

Hall, S.S. *Mapping the Next Millenium—The Discovery of New Geographies.* New York: Random House, 1992.

Strain, Priscilla, and Engle, Frederick. *Looking at Earth.* Atlanta: Turner Publishing, Inc., 1992.

Geographic Information Systems. U.S. Geological Survey poster. 1992.

Planetary Maps. U.S. Geological Survey poster. 1992.

Topographic Mapping. U.S. Geological Survey booklet. 1991.

U.S. Department of the Interior
U.S. Geological Survey

Evaluation of Teaching Packet for *Exploring Maps*

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Name (optional) _____

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My school is:
☐ urban ☐ suburban ☐ rural

Grade level of class _____

Number of students in class _____

I used this material to teach classes in:
☐ social studies ☐ art ☐ science
☐ math ☐ history ☐ English
☐ other

Check all that apply; elaborate if desired in spaces provided.

Design of poster and activity sheets

☐ well designed
☐ did not like design because

_____

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_____

Concepts

☐ presented clearly
☐ not presented clearly
☐ appropriate
☐ too difficult because

_____

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Teaching guide

☐ excellent
☐ adequate
☐ inadequate
☐ other _____

Activities

☐ worked well
☐ did not work well because

_____

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☐ favorite activity was

_____

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☐ least favorite activity was

_____

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Time

☐ appropriate
☐ too short to present activities adequately
☐ too long to keep students' attention

Questions

☐ excellent
☐ adequate
☐ inadequate
☐ other _____

Additional activities

☐ used some of these ideas
☐ didn't have time

Recommended reading

☐ easy to find and useful
☐ hard to find or hard to use

For more information about educational publications from the U.S. Geological Survey, call 1-800-USA-MAPS.

We'd like to hear more about what you thought of these activities, how they were used, and how they could be improved. Please use the space below, and continue on the back, if necessary. Thank you for your comments.